Musculus pygmaeus spec. nov., a Minute Mytilid from the High Intertidal Zone at Monterey Bay, California

(Mollusca: Pelecypoda)

BY

PETER W. GLYNN

Institute of Marine Biology, University of Puerto Rico
Mayagüez, Puerto Rico

(Plate 23; 1 Text figure)

INTRODUCTION

In the initial phase of an ecological study of a high intertidal community of organisms at the Hopkins Marine Station in Monterey Bay, California, over the period 1959-1961, numerous rusty-brown specimens of a minute mytilid were frequently encountered. The only individuals available measured between 0.8 and 1.0 mm in shell length and were tentatively identified by A. Myra Keen of Stanford University as juveniles of *Mytilus edulis* Linnaeus, 1758.

On August 26, 1961, many of the same tiny clams were released into a watch glass by a brooding female under observation in the laboratory. Soot-Ryen's (1955) diagnosis of the genera of the Mytilidæ shows that this adult individual is referable to the *Musculus* group. The specimen demonstrates the characteristic features of the genus with respect to shell morphology and musculature which may be summarized briefly as follows: a) anterior margin of shell crenulated, b) anterior adductor muscle distinct, c) radial sculpture absent from the median part of the outer shell surface, d) anterior retractor muscle situated anterior to the umbo, e) umbonal keel low, and f) periostracum without hair-like protuberances. The generic name *Modiolaria* has often been used instead of *Musculus*. As indicated by Dall (1915), however, both of these genera have the same type species, *Mytilus discors* Linnaeus, 1767; *Musculus* is the older name.

Further study of this and other adult specimens in consultation with Dr. Keen revealed the species to be an undescribed form closely related to the more northern species *Musculus taylori* (Dall, 1897). This mytilid was found to be very common in the high intertidal zone, and some information on its ecology and natural history follows the description.

Musculus pygmaeus Glynn, spec. nov.

(Figure 1, a and b, Table 1)

Description: Shell small, stubby, heavily built, and with an inflated appearance; profile of shell with keel-like dorsal margin, oval posterior margin; ventral margin with an irregular contour, indented conspicuously posteriorly and less so anteriorly; ventral portion of anterior margin terminal, forming a prominent forwardly directed protuberance and dorsally with rounded, stout beaks; ventral protuberance of anterior margin clearly visible in a dorso-ventral view as it juts forward between beaks; lateral surface of shell smooth except for concentric growth lines and a ridge that extends obliquely from posterior portion of ventral margin anteriorly towards beaks, terminating near thick mid-body region; two radial striæ extend from lower portion of each beak to anterior edge of ventral margin; some faint nicking is present in a more forward position along edge of protuberance; edge of shell finely scalloped at dorsal keel due to posterior hinge teeth and at antero-ventral margin due to radial striæ; few byssal threads extend through slightly gaping valves of ventral margin; ligament barely visible through widened slit of valves between dorsal keel and beaks; dorso-lateral thick portion of shell chocolate-brown, taking on an olive sheen along ventral margin; iridescent hæmatite red on parts of shell where periostracum is worn away.[1]

DISCUSSION OF PARATYPES

The range in shell length of 102 specimens measured with an ocular micrometer under 10X magnification is 0.6-4.5 mm (Table 1). Larger individuals appear more

[1] All descriptive color determinations in this paper were made with reference to Maerz & Paul (1950).

elongate and inflated than smaller forms; this relation is expressed in terms of the length-width and width-diameter ratios as functions of shell length in Figure 2. The data from which this graph was made are given in Table 2.

Variation of these dimensions with size and other features of the shell are shown pictorially in Figure 2 for a series of four typical individuals ranging in shell length from 1.0-3.9 mm. A keel on the dorsal margin is most evident in larger individuals. In small forms, on the order of 1 mm, the ventral margin has a smooth outline whereas larger specimens demonstrate increasing degrees of indentation of the ventral margin near the anterior and posterior ends. In very large *Musculus pygmaeus* the posterior indentation appears to be notched. A forwardly directed protuberance, forming the antero-ventral border, is not markedly developed in the young, but becomes prominent in forms from about 2 mm in length and greater. Likewise, the beaks appear confluent with the shell among small forms, developing later into distinct knobs. Among all sizes the ventral protuberance is clearly visible below the beaks in a dorso-ventral view. The ridge extending obliquely across the shell anteriorly from the postero-ventral margin is entirely absent in young forms, becoming barely detectable at a size of about 2 mm, and then increasing noticeably in older specimens. Radial striæ while absent in the young are evident in the 2 mm and greater size range. There may be one, two or three radial striæ present. Some forms show a delicate serration in a more forward position on the protuberance. Finally, the position of greatest shell diameter shifts from a dorsal location in small clams to the mid body region in larger individuals.

There is a distinct variation in shell color. Specimens above 3 mm in length agree well with the colors described for the holotype, *viz.* a chocolate-brown color on the dorsal and lateral portions, often grading into an olive sheen along the ventral margin. Also, an iridescent hæmatite red shows on smooth areas of the shell where the periostracum has recently been removed. Smaller individuals, under about 3 mm, generally have a completely hæmatite red shell or this color localized around the central and thicker portion of the body. Numerous shells in the size range 2.0-2.8 mm demonstrated a marginal

Table 1

Location of Type Material of *Musculus pygmaeus,* Field Data and Measurements of Shells.

Material	Museum		Collecting Locality	Collecting Date	Measurements (mm)		
	location	number			length	width	diameter
Holotype	Stanford Univ., Dept. Geology, Stanford, California	9747	Pacific Grove, Calif. 36°37′ N; 121°54′ W	March 4, 1962	3.6	2.1	1.9
20 Paratypes	same as above	9748	same as above	September 20, 1961	2.1±1.1 [1] 0.7—3.4	1.4±0.5 0.5—2.1	1.0±0.6 0.3—1.8
20 Paratypes	Mus. Nat. Hist., Pacific Grove, Calif.	1/81	same as above	March 4, 1962	1.8±1.1 0.6—3.8	1.1±0.7 0.4—2.2	0.9±0.5 0.3—2.0
20 Paratypes	Dept. Zool., Univ. British Columbia, Vancouver	5040	same as above	same as above	1.9±1.1 0.7—4.5	1.2±0.7 0.5—2.5	0.9±0.6 0.3—2.1
20 Paratypes	U.S. National Mus., Washington	635921	same as above	same as above	2.0±1.0 0.7—3.9	1.3±0.4 0.5—2.2	0.9±0.6 0.3—1.9
20 Paratypes	Instit. Marine Biol., Univ. Puerto Rico, Mayagüez	3388	same as above	same as above	1.8±1.1 0.6—4.0	1.1±0.7 0.4—2.2	0.9±0.5 0.3—1.9
1 Hypotype	same as above	3390	Two miles north of Cayucos, California 35°27′ N; 120°56′ W	November 2, 1963	3.1	1.9	1.6

[1] The means and standard deviations and the ranges are given for the measurements of the paratypes.

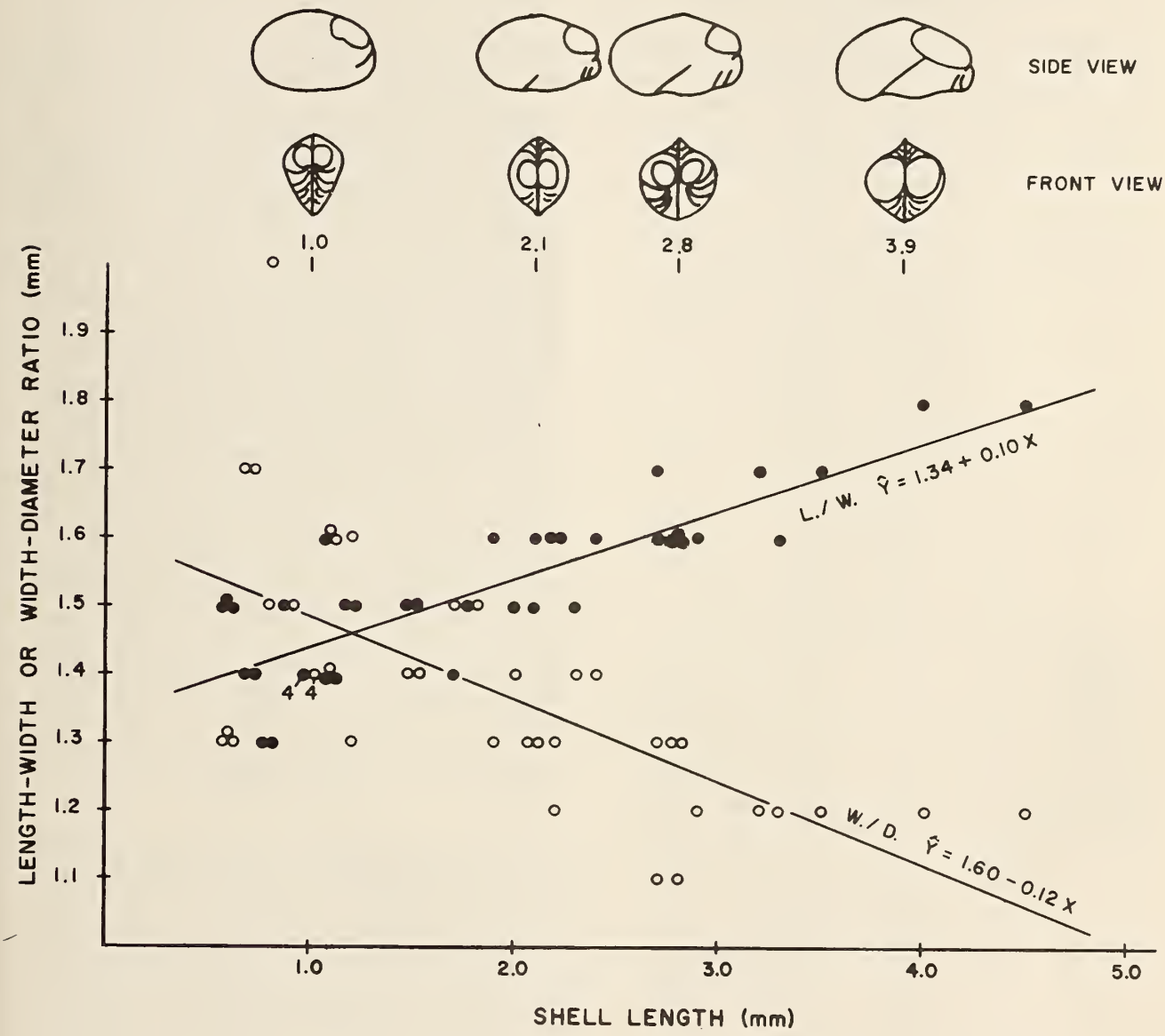

Figure 2: Scatter diagram of length/width (dots) and width/diameter (circles) ratios versus shell length in 40 specimens of *Musculus pygmaeus* from two lots of 20 paratypes each, deposited in the collections of the Institute of Marine Biology, University of Puerto Rico and the Department of Zoology, University of British Columbia. The prediction equations for the two relations illustrated lie along their respective curves. At a shell length of 1.0 mm four individuals each for the length/width and width/diameter ratios are indicated numerically since they occupy the same position on the graph. Side and front view sketches are shown along the top of the graph, illustrating pictorially the shell proportions and obvious shell sculpturing for the four different sized individuals selected. The shell length for each pair of figures is noted just below the front view.

Table 2

Individual Measurements and Ratios of Different Shell Proportions of 40 Paratype Specimens of *Musculus pygmaeus*

Material	Measurements (mm)				
	length	width	diameter	l./w.	w./d.
Institute of Marine Biology, University of Puerto Rico, Mayagüez. Museum No. 3388	4.0	2.2	1.9	1.8	1.2
	3.5	2.1	1.7	1.7	1.2
	3.3	2.0	1.6	1.6	1.2
	2.8	1.7	1.5	1.6	1.1
	2.7	1.6	1.4	1.7	1.1
	2.3	1.5	1.1	1.5	1.4
	2.1	1.4	1.1	1.5	1.3
	2.1	1.3	1.0	1.6	1.3
	2.0	1.3	0.9	1.5	1.4
	1.9	1.2	0.9	1.6	1.3
	1.5	1.0	0.7	1.5	1.4
	1.2	0.8	0.6	1.5	1.3
	1.2	0.8	0.5	1.5	1.6
	1.0	0.7	0.5	1.4	1.4
	1.0	0.7	0.5	1.4	1.4
	0.9	0.6	0.4	1.5	1.5
	0.7	0.5	0.3	1.4	1.7
	0.6	0.4	0.3	1.5	1.3
	0.6	0.4	0.3	1.5	1.3
	0.6	0.4	0.3	1.5	1.3
Department of Zoology, University of British Columbia, Vancouver. Museum No. 5040	4.5	2.5	2.1	1.8	1.2
	3.2	1.9	1.6	1.7	1.2
	2.9	1.8	1.5	1.6	1.2
	2.8	1.8	1.4	1.6	1.3
	2.8	1.7	1.3	1.6	1.3
	2.7	1.7	1.3	1.6	1.3
	2.4	1.5	1.1	1.6	1.4
	2.2	1.4	1.2	1.6	1.2
	2.2	1.4	1.1	1.6	1.3
	1.8	1.2	0.8	1.5	1.5
	1.7	1.2	0.8	1.4	1.5
	1.5	1.0	0.7	1.5	1.4
	1.1	0.8	0.5	1.4	1.6
	1.1	0.8	0.5	1.4	1.6
	1.1	0.7	0.5	1.6	1.4
	1.0	0.7	0.5	1.4	1.4
	1.0	0.7	0.5	1.4	1.4
	0.8	0.6	0.3	1.3	2.0
	0.8	0.6	0.4	1.3	1.5
	0.7	0.5	0.3	1.4	1.7

chrome lemon band extending from the antero-ventral border around to the posterior edge of the ligament. The smallest forms are often entirely of a hæmatite red. The absence of red and predominance of brown coloration in the largest specimens, except where the periostracum has been worn away, seems to be a result of the increase in thickness of the shell with age.

The interior of the shell in adult *Musculus pygmaeus* is iridescent over a blush rose background. The lateral diagonal ridge and the radial striæ are evident but less conspicuous internally. The posterior hinge teeth are strongly developed and are located along the dorsal margin in the region of the keel. Adult specimens usually have five or six hinge teeth in this position. Anterior or cardinal hinge teeth, which number three or four, are located at the forward edge of the protuberance at the anterior margin.

The shell musculature agrees with the descriptions given by Pelseneer (1911) and Soot-Ryen (1955) for the genus, and can be further characterized for this species as follows. In accordance with the anisomyarian condition of the Mytilidæ, the posterior adductor of *Musculus pygmaeus* is relatively very stout where it is inserted on the shell in a postero-lateral position from the dorsal keel. The anterior adductor muscle is not strongly developed. It is attached to the inner surface of the forwardly directed protuberance, in a position anterior to the umbo. The anterior retractor muscles, located forward of the anterior adductors, are long, running straight from their proximal origin on the foot to insert on the inner surface of the beaks. The posterior pedal retractor muscle fans out at its site of insertion on the shell; it extends posteriorly from the dorsal keel and terminates above the point of insertion of the posterior adductor muscle.

COMPARISON WITH CLOSELY RELATED SPECIES

Of the eleven species and one subspecies of *Musculus* on the western coast of North America (Oldroyd, 1924), *M. pygmaeus* resembles closely *M. phenax* (Dall, 1916) and *M. taylori*. Both *M. phenax* and *M. taylori* are small species in the genus, the holotype of the first measures 7.7 mm in length (Dall, 1915), and the holotype of the second measures 5.5 mm in length (Dall, 1897). The mean shell length and range, respectively, of a series of 15 specimens of *M. phenax* from the type lot deposited in the museum at Stanford University are 3.6±2.6 and 0.9—7.7 mm. Five specimens of *M. taylori,* including the holotype collected from Foul Bay, Victoria, British Columbia and four specimens from the Stanford University museum, gave a mean shell length and range, respectively, of 5.3±0.2 and 5.0—5.6 mm. Thirteen other paratypes of *M. taylori* from Victoria (deposited in the United States National Museum) range in shell length from 4.9 to 6.9

mm. These data show that *M. pygmaeus* is the smallest of the three species (as noted earlier, the largest individual has a shell length of only 4.5 mm, and the series of 20 paratype specimens with the greatest mean shell length measures 2.1±1.1 mm).

The standard deviation in *Musculus phenax* is relatively high—seven individuals measured less than 1.4 mm in length and eight greater than 4.0 mm. Since these specimens are from the type lot they were not dissected, but inspection into the interior of the shell through the gaping valves showed that this species, like *M. pygmaeus,* broods its young. The very small specimens in this sample probably represent young released recently from the adults. Eight specimens of *M. phenax* within the same size range as *M. pygmaeus* demonstrated similar length-width and width-diameter ratios in relation to shell length. *Musculus taylori,* although larger than *M. pygmaeus,* also seems to demonstrate these same shell proportions.

None of the three species shows radial sculpturing of the shell, but radial striæ are present and least evident in *Musculus phenax*. Only *M. phenax* and *M. pygmaeus* possess a prominent keel on the dorsal margin, whereas an oblique ridge is present only in *M. pygmaeus* and *M. taylori*. The ventral margin of *M. pygmaeus* is strongly indented near the anterior and posterior ends, less obviously indented in *M. taylori* and virtually smooth in *M. phenax*.

All three species inhabit shallow water, *Musculus taylori* in tide pools, *M. phenax* among algae and *M. pygmaeus* relatively high on the shore in holdfasts of the red alga *Endocladia muricata* (Postels & Ruprecht) J. G. Agardh, 1847. Presumably *M. phenax* lives in the intertidal zone since it was found in association with *Mytilus edulis,* which according to Shelford, *et al.* (1935) has an intertidal distribution in the vicinity of Victoria, British Columbia.

Musculus phenax and *M. taylori* have a more northerly distribution than *M. pygmaeus*. The type locality of *M. phenax* is St. George Island, Pribiloff group, Bering Sea. *Musculus taylori* has not been reported as far south as Monterey Bay, California (Smith & Gordon, 1948), and apparently is known only in the vicinity of the type locality at Victoria, British Columbia (Burch, 1945); this represents a geographical separation of 12° latitude or about 880 miles. One specimen of *M. pygmaeus* has been collected as far south as Cayucos, California (Table 1, hypotype), about 90 miles from Monterey Bay.

The possibility that *Musculus pygmaeus* is a known form introduced into the Pacific Coast of North America from some other similar environment demands close scrutiny. Many mollusks have been introduced into California from Japan in recent years with shipments of the oyster *Crassostrea gigas* (Thunberg, 1793); Bonnot (1935) in 1930 found 23 species of Japanese mollusks associated with this oyster at Elkhorn Slough, about 15 miles north of Monterey, California. McLean (1960) recently reported on the abundance in Elkhorn Slough of one of the same species reported by Bonnot, *viz. Batillaria cumingi* (Crosse, 1862). *Musculus pygmaeus* was compared critically with the original accounts or other detailed descriptions of the 11 species of *Musculus* which appear in Kuroda & Habe's (1952) check list and bibliography for the marine mollusks of Japan. The results of this comparison demonstrate that *M. pygmaeus* is distinct from all of these forms.

That *Musculus pygmaeus* was not introduced from the East Coast of North America was proved by an examination of the descriptions of the species listed by Johnson (1934). Numerous specimens of *M. lateralis* Say, 1822, a small ovoviviparous nestler, whose description agrees in some particulars with *M. pygmaeus,* were examined and found to be very different.

It is noteworthy that the population of *Musculus pygmaeus* living in the intertidal zone at Monterey Bay, California has the shortest shell length of all described species in this genus. Other small species reported in the literature (only the dimensions of the holotypes were given) are *M. arcuatus* (Gould, 1861) and *M. skomma* (McLean & Schwengel, 1944) each with a shell length of 5 mm.

ECOLOGICAL OBSERVATIONS

Musculus pygmaeus was found to be an important member of a high intertidal community of organisms dominated by the red alga *Endocladia muricata* and the acorn barnacle *Balanus glandula* Darwin, 1854 on the rocky coast in Monterey Bay, California (Glynn, in press). This particular association of organisms forms a band of approximately two feet in width, centered at a mean absolute elevation of 4.6 ft. in height above tidal datum. The lower and upper margins of this belt demonstrated a mean height above tidal datum of 3.7 and 5.8 ft., respectively, with exposure to the atmosphere amounting to 46% of the total time for the lower level and 95% for the upper level.

Musculus pygmaeus lives in intimate association with *Endocladia;* it attaches to the blades of the holdfast of the alga with its byssal threads. This mytilid has an erratic spatial distribution—being completely absent from extensive surfaces dominated by the alga or very abundant in other, seemingly identical localities. It was found in greatest abundance, but sporadically, at the lower margin of the association, especially in exposed, wave-swept areas. It was abundant throughout the year.

The mean occurrence at the low, center, and high levels was 11,260, 7,795, and 10 individuals/m² (extrapolated

from 400 cm² quadrat samples collected from the rock surface). In the same order, these gave mean dry weight biomass measurements of 10,390, 1,830 and 2.5 mg/m², equivalent to 2,078, 360, and 0.5 mg protein/m².[2] Compared with 30 other forms characteristic of the center of the *Endocladia-Balanus* association, *Musculus* ranked slightly under 4% numerically of the total mean composition and contributed a protein content of about 0.2% to the association.

To determine the absolute and relative abundance of *Musculus* actually living in the holdfasts of separate thalli of *Endocladia* three plants were removed from the substratum intact, including all animals living within the alga or clinging to the basal branches. The samples were collected at random from a dense stand of *Endocladia,* which had previously yielded numerous specimens of *Musculus,* and preserved in 70% ethyl alcohol. This area is located on the rocks at the Hopkins Marine Station, in a small, exposed surge channel on the small island immediately east of the Agassiz Laboratory. All of the larger animals, down to a minimum size of the smallest *Musculus* or about 0.5 mm, were sorted out from the samples and counted and the dry weight of each tuft of alga recorded.

It is apparent from the tabulation of absolute numbers (Table 3) of the 20 odd forms enumerated that *Musculus pygmaeus* was consistently the most numerous species present. The maximum number recorded was 1,065 individuals in the second tuft (sample 2) and the minimum was 398 individuals in the smallest tuft (sample 3). *Mytilus californianus* Conrad, 1837 was also very common, ranking second in abundance in samples 1 and 2, and fourth in sample 3. *Lasaea cistula* Keen, 1938 was relatively numerous in sample 3, with 46 individuals. Other abundant forms in the thalli were: one undetermined oligochæte species, syllid polychætes, *Balanus glandula, Dynamenella glabra* (Richardson, 1899), *Allorchestes ptilocerus* Derzhavin, 1937, *Agauopsis* sp., and *Filicrisia franciscana* (Robertson, 1910).

In terms of mean absolute abundance per gram dry weight *Musculus* demonstrated a value of 450.0, equivalent to a very high relative abundance of 78.1% (Table 4). *Mytilus* and *Lasaea* ranked second and third, with relative abundances of 9.8% and 2.4%, respectively.

Neither Colman (1940) nor Wieser (1952) in their studies on the animals inhabiting intertidal seaweeds on English shores include the genus *Musculus* as an important faunal element. Colman did not find *Musculus* in the lichen *Lichina pygmaea,* Linnaeus, 1758 which is apparently the ecological equivalent of *Endocladia,* and encountered only a single juvenile specimen of *M. marmoratus* (Forbes, 1838) in the predominantly subtidal brown

[2] This latter set of values is based on a mean nitrogen content of 3.2% and the assumption that proteins contain 16% nitrogen (Fruton & Simmonds, 1958, p. 27).

Table 3

Species & Taxonomic Groups	Samples		
	1	2	3
Rhodophyta			
Endocladia muricata	2.39 gm	1.76 gm	0.77 gm
Nemertea			
Emplectonema gracile	1	-	1
Annelida			
Oligochaeta			
One undetermined species	12	8	42
Polychaeta			
Nereis grubei	1	-	-
Syllis armillaris	2	-	-
Syllis spenceri	1	-	-
Syllis vittata	5	7	-
Syllidae (immature)	12	10	6
Arthropoda			
Cirripedia			
Balanus glandula	8	5	2
Pollicipes polymerus	-	3	-
Isopoda			
Dynamenella glabra	6	50	-
Amphipoda			
Allorchestes ptilocerus	16	8	-
Acarina			
Agauopsis sp.	29	28	1
Insecta			
Tipulidae (larvae)	-	-	3
Mollusca			
Gastropoda			
Littorina scutulata	-	1	-
Runcina sp.	-	-	1
Pelecypoda			
Lasaea cistula	9	14	46
Musculus pygmaeus	751	1065	398
Mytilus californianus	125	132	23
Saxicava arctica	1	-	1
Ectoprocta			
Filicrisia franciscana	2	2	1
Total number animals/sample	981	1333	525

Number of individuals of the various animal species found living in association with three separate thalli of *Endocladia muricata.* The alcohol-preserved dry weight of each alga is also listed. Omitted is an abundant microfauna, including such groups as foraminiferans, nematodes, harpacticoid copepods, ostracods and rhombognathinid mites. The number of individual colonies of *Filicrisia franciscana* was estimated from a count of the largest intact branches, since numerous small branchlets were probably broken away in handling. Immature syllids and tipulid larvae are groups which contain more than one species each, whereas the Oligochaeta appears to represent a single, undetermined species.

Figure 1 a

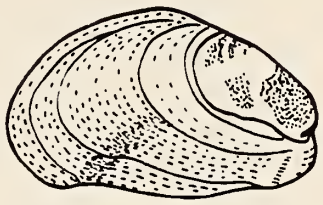

Figure 1 b

Figure 1 c

Figure 1: Photograph showing the right valve of *Musculus pygmaeus* (a); a schematic drawing of the same specimen to the same scale (b); and a photograph showing the right valve of *Musculus taylori* (c).